TERENCE: An Adaptive Learning System for Reasoning about Stories with Poor Comprehenders and their Educators

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Abstract. Text comprehension skills and strategies develop enormously from the age of 7-8 until the age of 11, when children advance as independent readers. Nowadays, more and more young children turn out to be poor (text) comprehenders: they demonstrate text comprehension difficulties, related to inference-making skills, despite proficiency in word decoding and other low-level cognitive skills. Though there are several pencil-and-paper reading interventions for improving inference-making skills on text, and specifically addressed to poor comprehenders, the design and development of adaptive learning systems for this purpose are lagging behind. The use of more intelligent adaptive learning systems to tailor such interventions to poor comprehenders has a tremendous potential. TERENCE embodies that potential. It is a Collaborative Project funded by the EC under the ICT Call 5 FP7-ICT-2009-5 (1 October 2010-30 September 2013). TERENCE will design and develop an intelligent adaptive learning system. In particular, the system's smart games will ask children to draw inferences about events of stories, in Italian and in English. Moreover, the system will allow teachers to choose and custom-tailor the types of stories and games according to the needs of their learners. The TERENCE consortium involves European experts in diverse and complementary fields (art and design, computer science, engineering, linguistics, evidence-based medicine, psychology), and sees the constant involvement of the end-users (poor comprehenders and their educators) from schools in the UK and in Italy. The paper overviews the TERENCE project.

1 Introduction

Developing the capabilities of children to comprehend written texts is key to their development as young adults. From the age of 7-8 until the age of 11, children develop as independent readers. Nowadays, more and more children in that age range turn out to be poor (text) comprehenders: they demonstrate difficulties in deep text comprehension, despite well developed low-level cognitive skills like vocabulary knowledge, e.g., see [2] for hearing poor comprehenders, and [5] for deaf poor comprehenders. In particular, several studies experimentally demonstrate that poor comprehenders fail to master the following reasoning skills in processing written stories:

(s1) coherent use of cohesive devices such as temporal connectives,

(s2) inference-making from different or distant parts of a text, integrating them coherently,
(s3) detection of inconsistencies in texts.

Nowadays, there is clear evidence that such reasoning skills (s1, s2, and s3) are very likely to be causally implicated in the development of deep text comprehension. In particular, experiments show that inference-making questions centred around (s1, s2, and s3), together with adequate visual aids, are pedagogically effective in fostering deep comprehension of stories, e.g., see [4].

However, finding stories and educational material that are appropriate for poor comprehenders is a challenge, and hence educators are left alone in their daily interaction with poor comprehenders. Most learning material for novice comprehenders is paper based, and is not easily customisable to the specific requirements of poor comprehenders, e.g., in the types, number or position of temporal connectives. Few systems promote general reading interventions, but they have high-school or university textbooks as learning material, instead of stories, and are developed for old children or adults, and not specifically for poor comprehenders.

TERENCE is a Collaborative Project funded by the EC under the ICT Call 5 FP7-ICT-2009-5 (1 October 2010-30 September 2013) and aims at designing and developing an intelligent *adaptive learning system* (ALS) [1]. The main end-users of the TERENCE ALS are: *learners*, namely, primary-school poor comprehenders, hearing and deaf, older than 7-8; *educators*, namely, primary-school teachers and support teachers, as well as parents of the TERENCE learners. The learning material (in English and in Italian) of the TERENCE ALS will be stories adapted to the specific requirements of poor comprehenders, and its reading interventions will be mainly interactive question-games centred around reasoning skills, like (s1), (s2), and (s3) above, that foster the development of deep text comprehension, both accompanied by adequate visual aids.

This paper outlines the TERENCE project and the work already conducted therein. It first specifies the chosen design methodology in Section 2. Then it outlines the conceptual model of the TERENCE ALS in Section 2. It continues with the design of the architecture in Section 4 and ends with a recap conclusive section.

2 The Design Methodology

The TERENCE system is developed following the user-centred design (UCD) methodology [3]. Generally speaking, the UCD places the end user, actively, at the centre of the design process, which is iteratively repeated until attaining the usability of the system. The iterative process revolves around the following main activities: a) analysis and specification of the context of use; b) analysis and specification of the user requirements; c) design prototypes; d) evaluate the prototypes against the specification of the requirements. In TERENCE we went through the first phase of the analysis of the context of use and the requirements, which resulted into the semi-formal specification of:

1. the characteristics of the users, like knowledge, skills, experience, education, training, physical attributes, habits and capabilities;

2. the tasks, like successful reading interventions by class teachers for improving reading comprehension;
3. the environments, divided into organisational, physical and socio-cultural characteristics that may influence the usage and acceptance of the system.

Our design of the conceptual model of the TERENCE ALS, which is outlined in Section 3 below, is based on such specifications and on the study of the state of the art of conceptual modelling for ALSs. In the UCD, the design evolves cyclically through refinements of the requirements, thus also the conceptual models of TERENCE will be updated accordingly. The following section outlines the current conceptual model.

3 The TERENCE Conceptual Model

As mentioned above, TERENCE is developed as an ALS. Its conceptual model includes:

1. the *domain model* for the learning material, that are stories and games,
2. the *user model* for the users, including the educator and learner sub-models,
3. the *adaptation model* for the adaptation learning process.

In the remainder, for space limitations, we only sketch the design of the domain model, and of the learner sub-model of the user model.

3.1 The Learner Sub-Model

The study of the state of the art for user modeling in ALSs and the specifications of the user characteristics, in particular, the poor comprehenders' reading skills, allowed the consortium to define the following sub-models of the user model: the learner sub-model; the educator sub-model; the expert sub-model.

The learner sub-model consists of three parts. The first structures general basic data about the learner such as name. The second is really specific to TERENCE: it structures information concerning the reading comprehension skills of poor comprehenders, analysed and specified in semi-formal format by the TERENCE consortium. By analysing such skills, the system will be able to adapt, to its learner, its learning material, structured as in the domain model. The third part of the learner sub-model structures data about the learner's interaction with the system.

3.2 The Domain Model

The main learning material of the TERENCE ALS consists in illustrated stories and games. During the analysis of the requirements and of the context of use of TERENCE, the tasks of the users were analyses and specified. Their specification allowed us to structure the learning material as in the domain model. This is divided into the story and game sub-models.

The story model represents data related to the stories that the learners interact with. For instance, stories are structured into books, each book has a genre and related avatars.

Furthermore, each story is annotated using natural language processing tools. The annotations, for instance, provide us with the events of which the story is made, specifying their actors, location and temporal relations.

Each story has associated games. Preliminary prototypes of the games are being designed by following assessed interventions for stimulating the reasoning skills on texts outlined in the introductory section and resulting from our user requirements' semi-formal analysis. For instance, according to this, poor comprehenders are in need of inference-making games that pose and solicit questions about relations between events in the stories, monitoring the learners' comprehension of the story flow, e.g., "Does the big eggshell crack before Mummy Duck watches it?". The game model represents the data for the TERENCE games, which are divided into smart games and relaxing games. Smart games are centered around inference-making questions that are built upon the annotations of the stories. As such, smart games are taxing for poor comprehenders and need to be paused by relaxing games (e.g., draw your favourite character), which keep the learners' attention and motivation alive. More details concerning their generation and resolution are in the following section.

4 The Architecture of the TERENCE System

The current logical architecture of our ALS is divided into three layers, namely, the data layer, the application layer, and the interaction layer. The data layer stores, for instance, the stories and games according to the domain model, and the information specific to each learner according to the learner model.

The application layer implements the adaptation engine, and the intelligent backbone responsible for the feedback on games (e.g., correct or incorrect answers to games). Finally, the interaction layer contains the users' interfaces.

The main modules of the adaptation engine of our ALS are a constraint-based automated reasoner and a natural language processing (NLP) module, consisting of a processor for English stories and one for Italian stories, that lay at the core of the adaptation engine and constitute its intelligent backbone, so to speak. The NLP modules serve primarily to annotate stories with specific XML tags. The tags are used for classifying stories as in the story sub-model, as well as for generating and giving feedback on the TERENCE smart games. According to the assessment of the students' performance on a class of games, the adaption engine will attempt to guide the students to the most adequate games and stories, following the adaptation model.

In the specific context of our ALS, tasks will be implemented through web services and their composition. For instance, let us refer to the generation of a temporal question-game centred around the question "Does the big eggshell crack *before* Mummy Duck watches it?". The composition will go as follows:

1. firstly, the system invokes an NLP web service operation, which takes the story as input and returns the annotations in the novel annotation language;
2. secondly, these annotations are taken as input, and an operation of the Automated Reasoner service deduces further temporal annotations as output, updating them;
3. finally, the updated annotations are taken as input and a further operation of the NLP web service generates as output the grammatically correct question-game.

A first clear advantage of such an approach is that it allows for the reuse of our architecture in other languages, by implementing the appropriate NLP services. Furthermore, since web services are accessible through HTTP calls, they can be invoked directly in their respective organisations, e.g. for keeping protected any eventual patent. Finally, the high-level operations might also be implemented with a programming-in-the-large paradigm, e.g. BPEL, thus allowing for an easy deploy of further operations, that become web services, and therefore re-usable to build up more complex tasks.

5 Conclusions

TERENCE is European project for the design and evaluation of an ALS specific for poor comprehenders and their educators. More in general, the project aims at offering innovative usability and evaluation methodologies, pedagogical models, AI technologies, and an ALS for reasoning about stories through smart games, in Italian and in English, all developed via a coordinated and cross-disciplinary effort of European experts in diverse and complementary fields (art and design, computer science, engineering, linguistics, psychology), and with the constant involvement of the end-users (poor comprehenders, deaf children and their educators) from schools in the UK and in Italy.

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References

1. P. Brusilovsky. Adaptive Hypermedia. *User Modeling and User-Adapted Interaction*, 11:87–110, March 2001.
2. K. Cain and J. Oakhill, editors. *Children's Comprehension Problems in Oral and Written Language: A Cognitive Perspective*. Guildford Press, 2007.
3. J. Gulliksen, B. Göransson, I. Boivie, S. Blomkvist, J. Persson, and A. Cajanger. Key Principles for User-centred Systems Design. 22(6):397–409, 2003.
4. National Reading Panel. Teaching Children to Read: An evidence-based Assessment of the Scientific Research Literature on Reading and its Implications for Reading Instruction. Technical report, National Institute of Child Health and Human Development, 2000.
5. P. Spencer and M. Marschark. *Evidence-based Practice in educating Deaf and Hard-of-hearing Students*. Oxford University Press, New York, NY, USA, 2010.